usual in such cases the main question is overlooked, viz, the clear and definite establishment of the fact. It is not sufficient to show that the lightning has struck several, or even many times within a limited radius, but one must show that it has not struck an equal number of times within the same area outside of that radius.

If the average of many years of observation shows that there really is a special frequency of lightning stroke in a limited region we have then to seek for the cause either near the ground or in the clouds. It is not likely that the cause consists in anything far below the surface of the ground. At the surface we know that tall trees, small hills, and tall buildings or monuments are most liable to be struck. As to the clouds we know too little about the cause of lightning to hazard any hypothesis. There are, however, three well established generalizations that will sometimes guide our investigations, viz, that thunderstorms are especially liable to begin in certain regions, that they pursue paths in directions radiating therefrom toward the east and northeast, and that they grow in severity up to a maximum at certain hours of the day. From these three principles it results that lightning will be most frequent along the favorite paths of thunderstorms and in those paths at certain hours of the day; if two favorite paths intersect, then the region of intersection will be especially rich in lightning strokes, provided that storms moving along these paths pass over that region at those hours of the day when the storm intensity is at a maximum.

Both from the practical point of view of the insurance companies, and from the philosophical point of view of the meteorologist, it is very desirable that we should have well established information relative to the distribution of lightning and thunderstorms, and the Editor will be pleased to publish a careful discussion of the complete record of all the lightning strokes that have fallen in any region as large as a township.

In conducting an investigation into the frequency of lightning, it is quite necessary to compare together equal areas; thus, it is often said that a city is less liable to severe strokes than the surrounding country, but, of course, this country area represents an area indefinitely larger than the city, and the comparison has no value unless we compare equal areas of the country and the city. It has been said that the western portion of the city of Washington (viz, Georgetown) is less subject to lightning than the rest of the city; but this "rest of the city" embraces an area that is more than ten times as large as Georgetown, and should, therefore, receive ten times as many strokes if they are evenly divided over the surface of the country.

Mr. W. M. Smith, voluntary observer at Van Wert, Ohio, states that there is a small region between South Avenue and Boyd Avenue, in that city, that is peculiarly subject to lightning strokes. An investigation of this and similar cases would doubtless prove instructive; but, as above stated, before undertaking to investigate the causes, we must first establish the fact very clearly and definitely by studying the frequency of strokes in equal areas of the surrounding region as carefully as we study the frequency in the electrical district itself.

The importance of considering the area and of determining the frequency per unit area is frequently lost sight of in statistical meteorology, and perhaps the most notable misapprehensions in this respect have been made with regard to the distribution of tornadoes, as shown in the following note.

TORNADO FREQUENCY PER UNIT AREA.

Several States of the Union have long been famous for tornadoes, and the popular dread of these destructive storms has been said to operate against the settlement of those States and against the peace of mind of the inhabitants. But the idea that tornadoes are very frequent has, to a large extent, resulted from a neglect to make proper allowance for the relative area of the respective States and of the tornado itself.

The chance of injury from a tornado evidently depends upon both the frequency of tornadoes per unit area and on the area covered by the path of the tornado, viz, the product of its length by its breadth. The area of destruction in any individual case will rarely amount to more than 25 square miles. Owing to the extremely local character of the destruction, our records of these storms become imperfect in proportion to the sparseness with which the country is settled, and in the newer States there is sometimes an apparent increase in the number of tornadoes, owing entirely to the increase in the inhabited area, and the consequent increased completeness of the record. In fact, our records for Kansas and Nebraska relate almost entirely to the eastern half of each State. In spite of the imperfection of our records the data contained in the following table has considerable value both to the meteorologist, the local inhabitant, and the insurance agent:

Tornado frequency.

States.	Area in units of 10,000 sq. miles.	Total number of tornadoes.			Annual average.	
		1874-1881. Finley.	1889-1896. Henry.	16 years.	Per State.	Per unit area.
Alabama	5.1	12	13	25	1.56	0.30
Alaska	51.7	0	0	0	0.00	0.00
Arizona	11.4	2	0	2	0.12	0.01
Arkansas	5.2	8	18	26	1.62	0.31
California	15.8	1	0	1	0.06	0.00
Colorado	10.4	1	1	2	0.12	0.01
Connecticut	0.5	2	0	2	0.12	0.24
Delaware	0.2	0	0	0	0.00	0.00
Dist. of Columbia	0.0	0	0	0	0.00	0.00
Florida	5.9	5	1	6	0.38	0.07
Georgia	5.8	29	12	41	2.56	0.44
Idaho	8.6	0	0	0	0.00	0.00
Illinois	5.5	50	29	79	4.94	0.90
Indiana	3.4	24	7	31	1.94	0.57
Ind Ter. and Okla	6.9	1	13	14	0.88	0.13
Iowa	5.5	26	28	54	3.38	0.61
Kansas	8.1	55	47	102	6.38	0.79
Kentucky	3.8	5	11	16	1.00	0.27
Louisiana	4.1	11	7	18	1.12	0.28
Maine	3.5	3	3	6	0.38	0.11
Maryland	1.1	8	3	11	0.69	0.63
Massachusetts	0.8	7	1	8	0.50	0.62
Michigan	5.6	13	5	18	1.12	0.20
Minnesota	8.4	21	22	43	2.69	0.32
Mississippi	4.7	9	15	24	1.50	0.32
Missouri	6.5	40	16	56	3.50	0.54
Montana	14.4	1	0	1	0.06	0.00
Nebraska	7.6	14	22	36	2.25	0.31
Nevada	11.2	1	0	1	0.06	0.00
New Hampshire	0.9	3	0	3	0.19	0.21
New Jersey	0.8	5	6	11	0.69	0.86
New Mexico	12.1	1	0	1	0.06	0.00
New York	4.7	20	5	25	1.56	0.33
North Carolina	5.1	14	2	16	1.00	0.20
North Dakota	7.1	4	2	6	0.38	0.05
Ohio	4.0	21	8	29	1.81	0.45
Oregon	9.5	0	0	0	0.00	0.00
Pennsylvania	4.6	17	13	30	1.88	0.41
Rhode Island	0.1	0	0	0	0.00	0.00
South Carolina	3.4	13	3	16	1.00	0.30
South Dakota	2.7	5	21	26	1.62	0.21
Tennessee	4.6	15	10	25	1.56	0.34
Texas	27.4	18	35	53	3.31	0.12
Utah	8.4	0	0	0	0.00	0.00
Vermont	1.0	2	0	2	0.12	0.12
Virginia	6.1	9	2	11	0.69	0.11
Washington	7.0	0	0	0	0.00	0.00
West Virginia	2.8	1	0	1	0.06	0.03
Wisconsin	5.3	11	10	21	1.31	0.25
Wyoming	9.8	1	0	1	0.06	0.01

The third column shows the number of tornadoes for each State for the eight years 1874–1881, as determined by Lieutenant Finley, and published in 1882. The fourth column contains the similar data for eight years, 1889–1896, as collected by Mr. A. J. Henry and published in the last annual volume of the Weather Bureau. To these items the Editor has added, in the second column, the area of the respective States, expressed in units of 10,000 square miles, or 100 miles square, as also finally the resulting averages showing the number of tornadoes annually per State and per unit area. The table shows that even in the so-called tornado States, the probability that any area of 100 miles square will be visited by a tornado in any year, is generally less than certainty, or unity, or less than 100 per cent. If these large areas be divided up into 100 smaller ones of 100 square miles each, or 10 miles square, then the probability that *some one* of these will be visited by a tornado within a year is less than 1 per cent, but the probability that *any specific one* of these smaller areas will be so visited is only the hundredth part of 1 per cent per annum, or 1 per cent per century. Within such a smaller area of 10 miles square the destructive path of the tornado, when it finally comes, will probably cover less than 25 square miles, so that the probability that *some one* of the 100 areas of 1 square mile will be struck is less than one-fourth of 1 per cent per century; but for *any specific area* or farm of 1 square mile the probability is much less than one-sixteenth of 1 per cent per century. In fact, the probability that a given house will be destroyed by a tornado is less than the probability that it will be destroyed by lightning or fire.

THUNDERSTORMS AT EUSTIS, LAKE COUNTY, FLA.

The voluntary observer (Mr. H. W. O. Margary) at Eustis, Fla., sends a detailed record of the thunderstorms at his station during June. His location is about 28° 45′ N., 81° 40′ W; altitude 60 feet above Lake Eustis, which is supposed to be 120 feet above sea level; the range of his horizon is quite large, being most restricted on the south side by heavy timber, but to the eastward there is no known limit, as he has observed lightning belonging to storms far beyond the coast line, and, in one case, as far away as the Bahamas, 250 miles, on which occasion the lightning appeared like a small segment of a circle rising from 3° to 7° above the horizon. To the westward his horizon is level over the low swamps, lakes, and river valleys. The view in all directions is entirely uninterrupted for distances ranging between 2 and 7 miles.

With these ample surroundings the temptation to make a minute study of thunderstorms is very great; but, of course, elaborate work in this direction at only one isolated station loses a great deal of the value that would attach to it if similar records had been kept by other observers distant a few miles from the central station. Mr. Margary's record shows that thunder was heard on the 2d, 3d, 4th, 5th, 6th, 7th, 12th, 13th, 14th, 15th, 16th, 21st, 22d, and 24th, or, in all, fourteen days, on all which occasions it is presumed by him that the storm was within 3 or 4 miles of his station. Some details of these storms, especially the azimuths at which they appeared and ended, when compared with similar observations at neighboring stations, will eventually give the exact location and path of the center. Other data can be at once used to give us, for instance, the hours of the day at which thunderstorms occur most frequently, or the diurnal curve of frequency. Thus, during June, at or near Eustis, the prevalence of thunderstorms within each hour of the day seems to have been as follows:

Midnight to 1 a. m.	1	Noon to 1 p. m.	0
1 a. m. to 2 a. m.	0	1 p. m. to 2 p. m.	2
2 a. m. to 3 a. m.	1	2 p. m. to 3 p. m.	2
3 a. m. to 4 a. m.	2	3 p. m. to 4 p. m.	2
4 a. m. to 5 a. m.	1	4 p. m. to 5 p. m.	4
5 a. m. to 6 a. m.	2	5 p. m. to 6 p. m.	1
6 a. m. to 7 a. m.	0	6 p. m. to 7 p. m.	1
7 a. m. to 8 a. m.	2	7 p. m. to 8 p. m.	2
8 a. m. to 9 a. m.	2	8 p. m. to 9 p. m.	3
9 a. m. to 10 a. m.	0	9 p. m. to 10 p. m.	1
10 a. m. to 11 a. m.	0	10 p. m. to 11 p. m.	1
11 a. m. to noon	0	11 p. m. to midnight	1

As no cyclonic storms visited Florida during this month, it is evident that the special frequencies between 3 a. m. and 9 a. m., between 1 p. m. and 5 p. m., and between 7 p. m. and 9 p. m. must all be determined by the alternation from warm sunshine at midday to cool radiation at night.

So far as we can make out from this record, which was apparently not prepared for the purpose of a study from this point of view, the thunderstorms appeared six times in the northwest, five in the north, two in the northeast, two east, three in the southeast, two in the south, three in the southwest, one in the west. The direction of motion of the storms in their paths is not easy to make out from the records at a single station, but, so far as can be gathered, the prevailing motion is from the southwest to the northeast. Mr. Margary especially notices a few storms that "came up with the wind," while the general rule was that they should "come up against the wind," and, as the wind is usually northeast, this would also indicate that the thunderstorms advanced from the southwest toward the northeast.

MECHANISM OF THUNDERSTORMS.

The advance of a storm against the wind may be interpreted as favorable to that view of the origin and structure of thunderstorms that has lately been so fully elaborated by E. Engelenburg in his memoir on the "Aerodynamic Theory of Thunderstorms," published in the XIXth volume (1896) of the Selections from the Archives of the Deutsche Seewarte. According to this view (which has been frequently expounded by the Editor since 1871) a thunderstorm is the result of the overturning of a considerable mass of the lower atmosphere, by which cool and especially dry air descends and runs under and pushes up warmer, moister air, which latter, after losing a small percentage of its moisture as rain, and a good deal of its heat by radiation from the clouds, becomes in its turn again the heavier, and descends beneath other moist air. This process of descent and ascent constitutes a vertical rotation around a horizontal axis, and will continue indefinitely until the rolling mass of air comes into regions where the topography of the ground or the presence of very dry air or very cold air near the ground as in the early morning hours, breaks up the thermodynamic process that is essential to the storm's automatic propagation. In the course of this rotation around a horizontal axis, it may occasionally happen that the rotation which is never strictly vertical, becomes considerably inclined, and the winds become so severe that the storm is spoken of as tornadic; but the true tornado with its funnel-shaped cloud is not to be considered as belonging to this class of thunderstorms. Beside the rolling thunderstorm, which advances broadside forward, there is another class of storms to which the tornado and the waterspout belong. In this class of storms the motive power is found in the buoyancy of a great cumulus cloud under whose center the lower air ascends because it is pushed upward into the region of abnormal low pressure within the cloud. Another class of thunderstorms includes those formed by air that is pushed upward by being blown against obstacles such as mountains, these often have no special internal maintaining power and may soon die away.

FREQUENCY OF THUNDERSTORMS.

We have received from Mr. H. H. Moore, voluntary observer at Windsor (five or ten miles north of Hartford, Conn.), a record of the number of days on which thunder has been audible; it embraces all days on which thunderstorms were heard by the observer without regard to the distance of the storm. Mr. Moore's record can be thrown into the following tabular form so as to give the average for each month of the year: